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(54) IMPROVEMENTS IN TAPE RECORDER HEADS

(71) We, RACAL-THERMIONIC LIMITED (formerly Thermionic Products (Electronics) Limited), a British Company, of Hythe, Southampton, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a ring-type transducer head for a tape recorder.

Transducer heads of the above type comprise a ring of magnetic material bearing a winding for effecting a recording on a tape or a playback of a recording thereon, and for this purpose provide a gap i.e. a magnetic discontinuity, in the magnetic material of the ring at the place where in use of the head, the tape makes contact therewith. Conventionally the gap is constituted by a physical gap in the magnetic material of the ring and, in consequence, ring type heads are formed by making them up from two symmetrical and separately produced halves. The mating surfaces of the two halves of each head, because they define the gap, need to be ground and polished, and the head is then formed by joining the two halves with a non-magnetic shim, e.g. of beryllium-copper or of mica, between them to constitute the gap. This manner of construction, however, incurs disadvantages. Thus, great precision is needed in grinding and polishing the mating surfaces, and the performance of the head is very dependent on the microstructure of the non-magnetic material filling the gap. Further, the performance of the head varies continuously with wear and the magnetic material Ferrite which in itself would be advantageous as the transducer material, cannot be satisfactorily used in this form of construction because, being brittle, it crumbles at the gap under the abrasive action of the tape.

It is an object of the present invention to provide a gapless ring-type transducer head for a tape recorder, in which what would otherwise be the gap *per set* is constituted otherwise than by means of a physical discontinuity of the magnetic material of the ring.

According to the present invention, a gapless ring-type transducer head for a tape recorder has an additional winding provided magnetically to saturate a portion of the ring of magnetic material, and the ring is formed, and the additional winding located, so that the saturated portion provides a curved boundary which meets the face of the ring to be contacted by the tape in use of the head (hereinafter called the front face) and so that the tape when in contact with that face, lies on a tangent, or substantially on a tangent, to the curved boundary.

It will be understood that the saturated portion, in effect, constitutes a magnetic discontinuity of the ring since its incremental permeability is extremely low viz:— of the order of that of free space. The portions of the ring separated by the saturated portion provide the pole tips of the transducer which are reduced to zero cross-sectional area where the curved boundary meets the front face of the ring. The length of the gap (l) formed by the saturated portion depends on the radius of curvature (r) of the curved boundary at the front face of the ring and on the distance (h) measured along a line normal to the front face, from that face to the depth at which the poles are just saturated by the flux of the tape. The above parameters are related as follows:— $l = 2\sqrt{r}.\sqrt{2r-h}$; h typically being 10 micro-inches and r of the order of thousandths of an inch.

The present invention makes use of the known phenomenon that at saturation, the magnetic flux flows in the regions of the material of minimum cross-sectional area. Accordingly, the present invention may provide the saturated portion by forming a hole to pass through the limb or section of the ring bearing the front face, on an axis parallel to that face and perpendicular to the plane of the ring, and the additional winding

[*Price 25p*]

is passed through the hole. The hole may be located so that it lies mid-way between the front face and the opposite face, which may be referred to as the rear face, of that limb or section of the ring, at the inner periphery of the ring and centred on a line lying normal to the front face and bisecting the ring, or it may be off-set from this position in that it may lie nearer to the front face than to the rear face. In the former case, the saturated portion is cylindrical in shape with the peripheral surface of the cylinder, at opposite ends of a diameter, meeting the front face and the rear face respectively; and in the latter case, the saturated portion is generally cylindrical but contiguous with a band of saturation passing round the entire inner periphery of the ring with part of the peripheral surface of the generally cylindrical part forming said curved boundary meeting the front face of the ring. Alternatively, a notch may be formed in the ring from the rear face and directed towards the front face in a line normal to the front face and bisecting the ring with the additional winding diposed on the ring away from the notch. In this case, the saturated portion consists of a band passing round the inner periphery of the ring except at the notch where a loop is formed to pass round the notch, the apex of the loop forming the curved boundary of the saturated portion meeting the front face of the ring.

In use of the transducer head according to the present invention, there is an optimum saturation current for achieving maximum output in playback and minimum gap width. Below that current, no completely saturated portion is created and part of the collected flux from the tape is shunted through the portion of incomplete saturation while above the optimum current, the radius of curvature of the curved boundary of the saturated portion increases and the gap length increases.

The ring of the transducer may be made of any magnetic material but the materials: Mumetal (Registered Trade Mark), Radiometal, Alfenol and Ferrite, which are alloys of high magnetic permeability, may be particularly mentioned. With metallic magnetic materials which are subject to work hardening and changes of magnetic properties, the ring may be made by photo-etching or spark machining of annealed material. Alternatively, ordinary machining processes may be used such as blanking of untreated material, and the material subsequently annealed to restore magnetic properties. If Ferrite is used, the ring may be made solely by moulding although finishing by machining, for example, with a diamond tool or ultrasonic tool or by using a jet of air-borne abrasive, is preferred. The magnetic properties of Ferrite are not affected by these processes and there is no need to perform any treatment to restore magnetic properties. In order to strengthen the ring, the hole or notch as the case may be, may be potted with an epoxy resin or other hard-setting material. Preferably, the section bearing the front face is first formed, whether separately from or integrally with the remainder of the ring, without the hole or the notch as the case may be and then the hole or the notch as the case may be formed in the section.

It is preferred to construct the ring from two separately formed sections namely, one in the form of a general U-shape and one in the form of a generally rectangular bar to bridge the upstanding limbs of the U at the open end thereof, the bar at the lateral face remote from the U constituting the front face and being in the form of an arc to provide minimum contact with the tape. The bar section before assembly with the U-shaped section is formed with the hole or notch as the case may be and in the former case, has the additional winding mounted thereon to pass through the hole. In the latter case, the additional winding may be mounted on one of the limbs of the U-shaped section. The embodiment of the invention employing the notch is, therefore, particularly well suited for making up a multi-channel head. Thus, the U-shaped sections each bearing the additional winding and the normal operating winding preferably mounted on the opposite limb of the U-shaped section to that bearing the additional winding, are mounted each in a separate channel of a holder, and the bar sections are each mounted in a slot of a further holder shaped so that the bar sections can be profile ground and polished in the holder to the required form. The two holders are then united to leave the front faces of the bar sections exposed so that in use of the head, the tape can be brought into contact therewith.

If metallic material is used for the rings, the notches can be cut using any of the following three methods:

1. Spark machining with a wire electrode.
2. By a sawing action with a fine nylon thread impregnated in an etching solution—ferric chloride is satisfactory for most materials.
3. By a sawing action with a thread or wire impregnated in a fine abrasive such as diamond or silicon carbide.

None of these methods affects the magnetic properties of the bar sections, since they involve minimal mechanical shock, and preannealed material can therefore be used. If Ferrite material is used, the notches can be cut by the following methods:

1. Slitting with a fine high speed diamond saw.
2. Ultrasonic machining.
3. Slotting with a jet of air-borne abrasive particles.

After the notch is cut, the mechanically weakened region in the bar section is reinforced by potting with an epoxy resin.

Heads constructed with magnetic discontinuities by any one of the methods described above have the following advantages over conventionally constructed heads.

1. The effective gap lengths provided are considerably smaller than the smallest mechanical dimensions involved in fabrication of the head, and therefore require correspondingly less precision in manufacture than conventionally gapped heads of identical gap-length.
2. The shape of the effective pole-pieces is at all times the ideal shape, irrespective of wear; flux-collecting properties in replay are therefore enhanced.
3. Because there is no mechanical discontinuity in the heads, but a smooth unbroken contour, heads constructed of Ferrite have none of the problems of crumbling at the gap, as do conventionally constructed ferrite-heads.

Embodiments of the present invention are illustrated, by way of example only in the accompanying drawings in which:—

Figures 1 to 3 are side elevations respectively of the ring-type heads of an example and two variants thereof, of the invention;

Figure 4 is a sectional end elevation of an assembly of a multi-track head in accordance with the present invention;

Figure 5 is a sectional side elevation of the assembly of Figure 4; and

Figure 6 is a plan view of a part employed in the assembly of Figure 4.

Referring to the drawings, it may be seen from Figures 1 to 3 that the ring type heads are formed of two sections, namely a generally rectangular bar section A and a general U-shaped section B surmounted by section A. The two sections are joined together by embedding in any suitable matrix within a casing in a conventional manner. The section A in each case has the front face F1, F2 and F3 respectively of arcuate shape to minimise contact with the tape. In the embodiment of Figure 1 a hole 4 is formed to pass through section A with the axis of the hole parallel to the front face; and the hole is located to be mid-way between the front face F1 and the opposite or rear face R1 at the inner periphery of the ring, on a line lying normal to the front face and bisecting the ring. The hole carries a saturation winding SW1 which on activation creates a saturated portion ST1 about the hole. The saturated portion is cylindrical in shape and the peripheral surface of the cylinder, i.e. the boundary of the saturated volume, at opposite ends of a diameter, meets the front and rear faces respectively of the section. The portions PT_N and PT_S of the section separated by the saturated portion constitute the pole tips of the transducer and are reduced to zero cross-sectional area where the curved boundary of the saturated portion meets the front face of the ring. The normal or playback winding RW1 may be passed round any other section of the ring but preferably is carried on the crosspiece CP of the U-shaped section. The embodiment of Figure 2 is generally similar except that the hole is off-set in that it lies nearer to the front face F2 than to the rear face R2. As a result when the saturation winding SW2 is activated a band of saturation PBS passes round the entire inner periphery of the ring so that the generally cylindrical volume of saturation ST2 is contiguous with the band PBS as shown in Figure 2. In this Figure, the normal or playback winding RW2 is again carried on the cross-piece CP of the U-shaped section.

In the embodiment of Figure 3 a notch N is used in place of the hole of the embodiments of Figures 1 and 2; the notch passes from the inner periphery of the ring towards the front face F3 along a line bisecting the ring and running normal to the front face. The saturation winding SW3, in this case, is carried on the limb L1 of the two limbs of the U-shaped section while the normal winding RW3 is carried on the other limb. On activation of the saturation winding a band PBS of saturation passes round the entire inner periphery of the ring but at the notch, it follows the periphery of the notch round to create the curved boundary of saturation meeting the front face F3 as shown.

The latter embodiment is particularly suitable for making up a multi-track head. This may be effected by using holders as shown in Figures 4 to 6. Two holders are employed, one BH for the U-shaped sections B and one TH for the bar-shaped sections A. The holder BH is trough-shaped and the U-shaped sections with their windings are embedded in a suitable hardening matrix M, e.g. an epoxy resin, therein. The bar sections as used for assembly are in an unfinished condition and fit into slots S in the holder to occupy the position shown in outline in Figure 4, to expose the front and rear faces of each of the bar sections. The bar sections are then profile ground and polished using conventional techniques and the notches N cut therein, and the holder with the finished sections fitted over the holder BH to form each ring head. The portions of the limbs of the U-shaped sections occupy

part of the slots to come into mating contact with the rear faces of the bar sections and the two holders are united by using further hardening matrix, to fill the gaps G (Figure 4) underlying the bar sections.

While the heads of the present invention are predominantly useful as replay heads, the heads can be used as record heads, by passing suitable current through the record/replay winding. It has been found in practice however, that this use is less advantageous, because when the current is sufficient to effect recording the recording flux interacts with the saturation flux, and causes the effective gap to widen. In replay, the flux off the tape is much smaller than the saturation flux, and the effect does not occur.

WHAT WE CLAIM IS:—

1. A gapless ring-type transducer head for a tape recorder wherein an additional winding is provided magnetically to saturate a portion of the ring of magnetic material, and wherein the ring is formed, and the additional winding located, so that the saturated portion provides a curved boundary which meets the face of the ring to be contacted by the tape in use of the head (hereinafter called the front face) and so that the tape when in contact with that face, lies on a tangent or substantially on a tangent to the curved boundary.

2. A transducer head according to Claim 1, wherein the ring is formed with a hole to pass through the limb or section of the ring bearing the front face, on an axis parallel to that face and perpendicular to the plane of the ring, and the additional winding is passed through the hole.

3. A transducer head according to Claim 2, wherein the hole is located mid-way between the front face and the opposite or rear face of that limb or section of the ring at the inner periphery of the ring, and centred on a line lying normal to the front face and bisecting the ring.

4. A transducer head according to Claim 2, wherein the hole is centred on a line lying normal to the front face and bisecting the ring and lies nearer to the front face of that limb or section of ring than to the rear face thereof.

5. A transducer head according to Claim 1, wherein the ring is formed with a notch in the limb or section bearing the front face, passing in from the opposite or rear face of that limb or section of the ring towards the front face on a line normal to the front face and bisecting the ring, and wherein the additional winding is disposed on the ring away from the notch.

6. A transducer head according to any one of the preceding claims 2 to 5, wherein the hole or the notch as the case may be, is potted with a hard-setting material to strengthen the section bearing the hole or the notch as the case may be.

7. A transducer head according to Claim 6, wherein the hard-setting material is an epoxy resin.

8. A transducer head according to any one of the preceding Claims, wherein the ring is formed of an assembly of two separately formed sections, namely, one in the form of a general U-shape and one in the form of a generally rectangular bar to bridge the upstanding limbs of the U-shaped section at the open end thereof, the lateral face of the bar remote from the U-shaped section constituting the front face and being in the form of an arc to provide minimum contact of the tape therewith.

9. A transducer head according to Claim 5 and Claim 8, wherein the additional winding is mounted on one of the limbs of the U-shaped section.

10. A multi-channel transducer head comprising a plurality of heads according to Claim 8 or 9, wherein the U-shaped sections are carried in one holder and the bar sections in a second holder, the two holders being united to hold each head in the assembled condition and the plurality of heads in position in relation to one another.

11. A transducer head according to Claim 8 or Claim 9 and 10, wherein the normal winding of the head for playback and recording is mounted on the opposite limb of the U-shaped section to that bearing the additional winding.

12. A transducer head according to any of the preceding claims, wherein the ring is formed of metallic material.

13. A transducer head according to Claim 12, wherein the ring is formed by photo-etching or spark machining of annealed material.

14. A transducer head according to Claim 12, wherein the ring is formed by blanking of non-annealed material and the formed ring is then annealed.

15. A transducer head according to any of preceding Claims 12 to 14, wherein the metallic material is any well-known magnetic alloy having high magnetic permeability.

16. A transducer head according to any of preceding Claims 1 to 9, wherein the ring is formed of Ferrite.

17. A transducer head according to Claim 16, wherein the head is formed by moulding of the Ferrite.

18. A transducer head according to Claim 17, wherein the moulded Ferrite is finished by machining.

19. A transducer head according to Claim 18, wherein the machining is effected by means of a diamond tool or an ultra-

sonic tool or by the use of a jet of air-borne abrasive.

20. A transducer head according to any of the preceding Claims 2 to 19, wherein the section of the ring bearing the front face is first formed, whether separately from or integrally with the remainder of the ring, without the hole or the notch as the case may be, and the hole or the notch as the case may be is then formed in the section.

21. A transducer head according to Claim 5, wherein the ring is made of metallic material; and wherein the notch is cut by:

(1) spark machining with a wire electrode;

(2) sawing with a fine nylon thread impregnated with an eaching solution; or

(3) sawing with a thread or wire impregnated in a fine abrasive.

22. A transducer head according to Claim 21, wherein the etching solution is ferric chloride.

23. A transducer head according to Claim 21, wherein the fine abrasive is silicon carbide.

24. A transducer head according to Claim 5, wherein the ring is made of Ferrite; and wherein the notch is cut by:

(1) slitting with a fine high speed diamond saw;

(2) ultrasonic machining; or

(3) slotting with a jet of air-borne abrasive particles.

25. A ring-type transducer head for a tape recorder, substantially as hereinbefore described, with reference to Figures 1, 2 or 3.

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1251372 COMPLETE SPECIFICATION
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Sheet 1

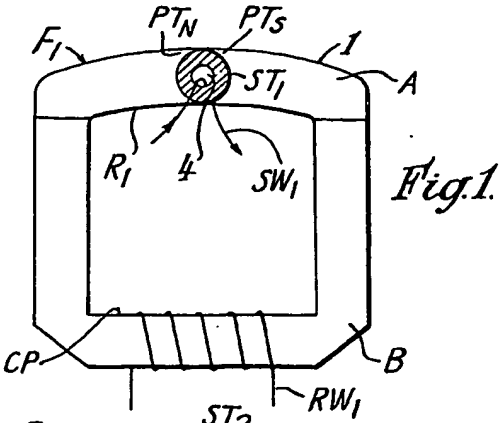

Fig.1.

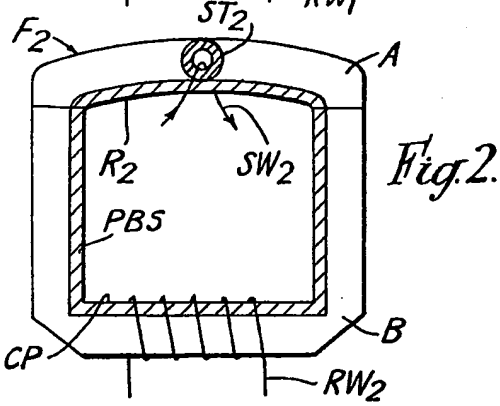

Fig.2.

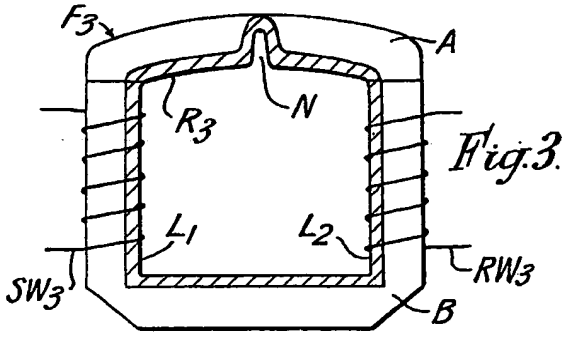

Fig.3.

1251372 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 2

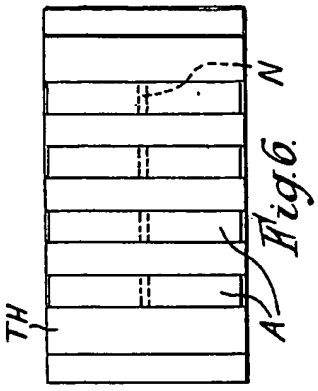

Fig.6.

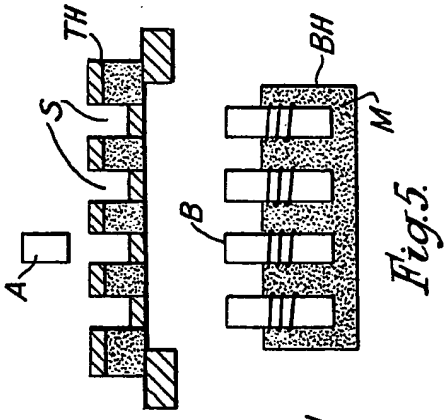

Fig.5.

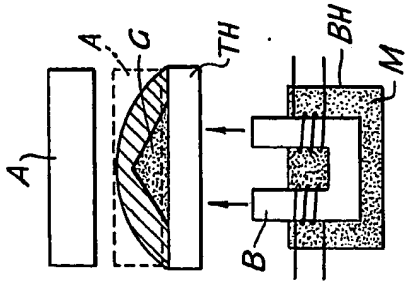

Fig.4.